Long-Term Program of Absolute Gravity Measurements in Antarctica

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Absolute gravity measurements are necessary to build models of the geoid. Moreover, repeated measurements are complementary to precise positioning observations to constrain both the ice-mass variations over the polar regions and the post-glacial rebound. The ground gravity measurements are also necessary to discriminate between the different results provided by space gravimetry. To study the long-term gravity variations, the appropriate method is to repeat absolute gravity observations every few years at selected stations spread all around Antarctica.

1. Space gravity measurements

Since 2002, the GRACE twin satellites have measured the time variation of the Earth's gravity field (Fig. 1). However, the estimates of the gravity variation depend on the length of the time series and solutions that are provided by different analysis centers.

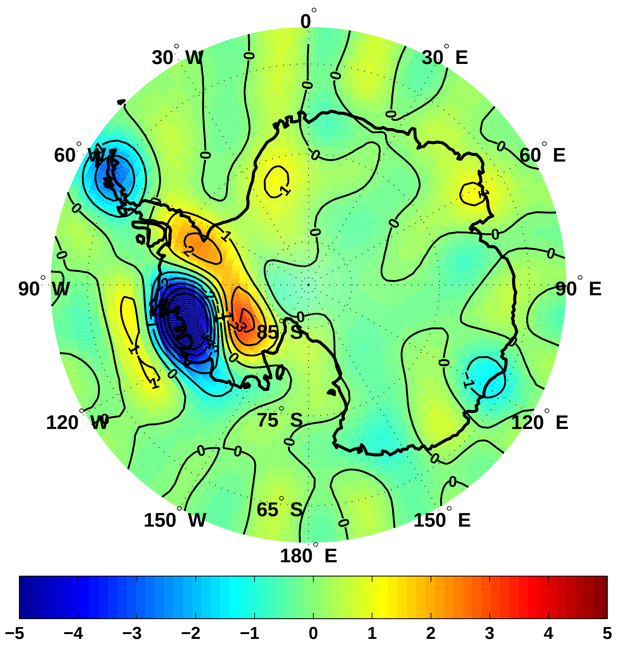

Figure 1. Annual gravity variation over Antarctica (in μGal/yr) from GRACE data (January 2003 - January 2009). Blue (respectively red) corresponds to gravity decrease (resp. increase). The same pattern was obtained by other studies, although the amplitude of the variation is quantitatively different (Courtesy of A. Mémin).

2. Ice mass variation

Long-term gravity variations are mainly caused by the post-glacial rebound (PGR) and present-day ice melting. The latter can be estimated by removing the modeled PGR from the gravity signal. Because of large uncertainties in both the PGR and space gravity data, estimates of the ice mass changes are highly variable (Fig. 2).

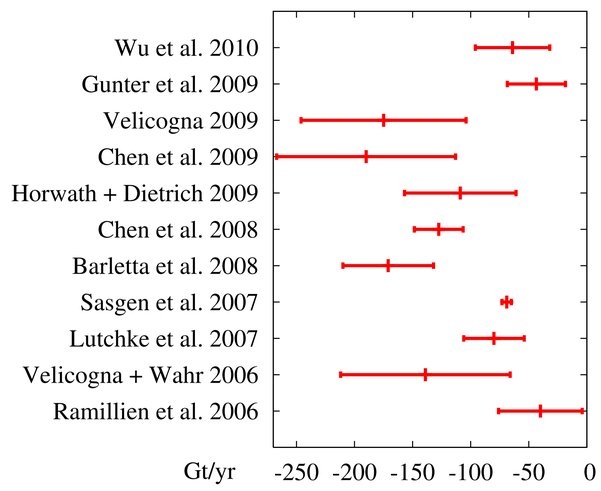

Figure 2. Estimates of annual ice mass loss (in gigaton per year) in Antarctica from GRACE data and PGR modeling.

3. Ground gravity measurements

The ground gravity measurements are complementary to the space measurements. The ground gravity variation δg is related to the space gravity variation Δg by $\delta g = \Delta g + \mathbf{u} \cdot \nabla g$, where $\mathbf{u}$ is the displacement of the ground and ∇g is the gradient of the gravity. In the last 20 years, the absolute gravity has been measured at different stations (Figs 3 and 5). Most of the time, the gravimeter is a ballistic FG5 gravimeter designed by Micro-g LaCoste (Fig. 4) .

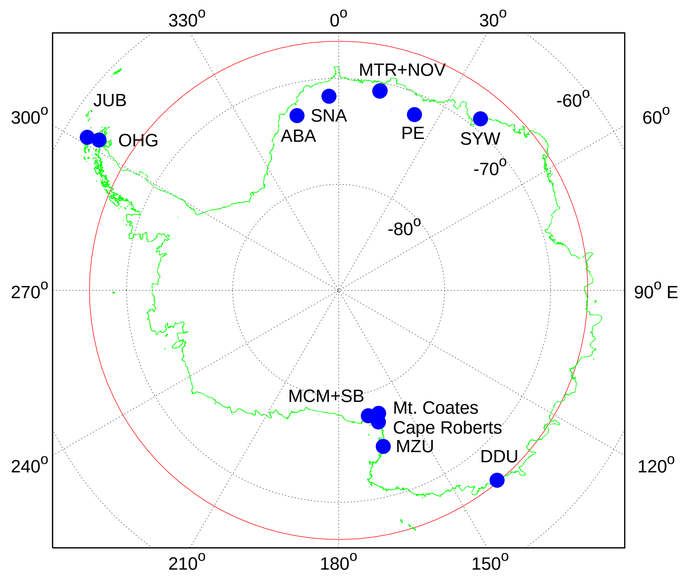

Figure 3. Sites with absolute gravity measurements.

- ABA = Aboa [FIN] 1993, 2003
- SNA = Sanae IV [ZA] 2003
- NOV = Novolazarevskaya [RU] 2003
- MTR = Maitri [IND] 2004
- PE = Princess Elisabeth [B] 2010
- SYW = Syowa [J] 1991, 1992, 2000, 2003
- DDU = Dumont d'Urville [F] 2000, 2006, 2011
- MZU = Mario Zucchelli Station [I] 1990, 1995, 1997, 2009, 2011
- Cape Roberts [NZ] 1997
- Mt. Coates [USA] 1997
- MCM = McMurdo Station [USA] 1995, 1997, 2009, 2011
- SB = Scott Base [NZ] 2009, 2011
- JUB = Jubany [ARG] 1997
- OHG = O'Higgins [CHL] 1997, 2011

Figure 4. FG5 absolute gravimeter installed at MZU (Terra Nova Bay, I) in November 2009.

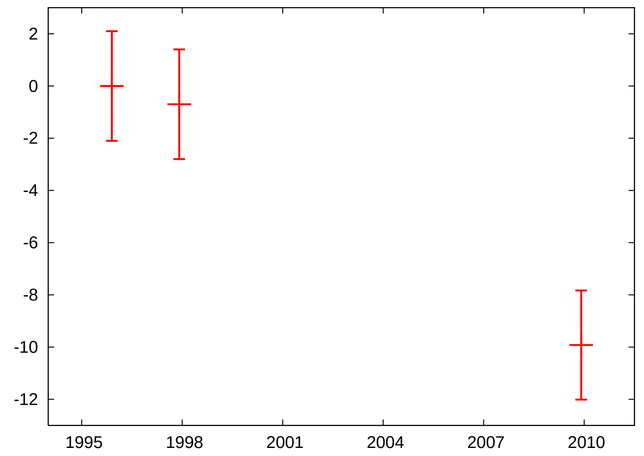

Figure 5. At MZU (Terra Nova Bay, I), gravity minus the 1995 observation $g_{1995} = 982\,865\,664.1$ μgal, where 1 μgal $= 10^{-8}$ m/s^2.

4. Project of absolute gravity measurements in Antarctica

Goal

Our objective is to establish an international program of absolute gravity measurements in Antarctica. It will consist in performing, every year, measurements at 3 or 4 stations located in the same region, for instance in the same quadrant, and repeating the measurement every 4 years at a same station. Every station should be visited at least 3 times; the duration of the program will therefore be 12 years at least.

Stations

- The stations should be spread around the continent.
- The gravity measurements should be continued at the stations shown in Fig. 3.
- The regions where the gravity variations are the most significant, for example the Antarctic Peninsula and West Antarctica, should be particularly well monitored.

Technical and logistical requirements

- At the stations where no perennial benchmark can be inserted into a stable concrete floor inside a heated and quiet room, building of a perennial pillar in a minimum 4× 4 m² hut.
- Once a year, deployment of 2 or 3 scientists or engineers and transportation of 500 kg of equipment.
- Logistic support to transfer people and equipment between the stations.
- The duration of a campaign will depend on the number of stations to be visited. Because of the extreme weather conditions that often cause delays in the scientific operations, 7 to 10 days should be allowed for a measurement at a single station.

Expected outcomes

Theoretical and observational efforts are simultaneously oriented towards more accurate modeling and measurement of the gravity changes in the polar regions. This project only deals with the observational side of the research. Through a validation by ground gravity measurements of the observations provided by the GRACE satellites now, and GRACE-II satellites in the future, the expected results are better contraints on the viscous structure of the Earth's mantle and on the estimate of ice melting in Antarctica.